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THE PERIODS OF ROTATION OF MERCURY AND VENUS, AND THE SATELLITES OF THE SOLAR SYSTEM.

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Long ago, when our moon was in a plastic condition and the earth's attraction forced great tidal waves of liquid or gaseous matter to roll over her surface, a marvelous effect was produced. The rotation period of the moon was gradually brought into coincidence with the period of her revolution.

The principle involved in such planetary interaction is known as the theory of "tidal friction", and was first announced to the world by the German philosopher, Kant, in 1754. But not until near the middle of the nineteenth century did it begin to play any important part in astronomical theories.

In this paper I propose to consider the synchronism of the rotation and revolution periods of the planets Mercury and Venus, and of all the satellites of the solar system, basing my argument upon recent astronomical observations. Up to the year 1889, no definite period of rotation had been assigned to the planet Mercury; but in that year the Italian astronomer, Schiaparelli, discovered from certain marks upon the surface of the planet that the revolution of Mercury around the sun and his rotation upon his axis were coincident, each requiring a period of about 88 days.

In the year 1666, Domenico Cassini, an Italian, estimated the period of the rotation of the planet Venus at 23 hours and 21 minutes. Another observer placed it at 24 days, 8 hours; Schroeter gave it a period of 23 hours and 28 minutes; and others still put it at 23 hours, 21 minutes, and 22 seconds. The first accurate observations upon Venus, made in this case also by Schiaparelli, with his splendid equipment, his unrivaled Italian skies, and his unsurpassed powers of vision, have given us something reliable and definite, establishing almost beyond a doubt that Venus rotates in precisely the same time that she requires to perform one revolution, that is 224 days, 7 hours.

Mercury and Venus, of all the planets, are the only ones that resemble our moon in their periods of rotation and revolution, and, just as our satellite turns but one face towards the earth, so in like manner do our inner neighbors turn but one face towards their primary, the sun.

"We can scarcely, indeed, realize, without some approach to dismay, the physical condition of a globe turning always the same face towards the sun. Over one hemisphere, the perpetual glare of unending day; on the other, darkness without the hope of dawn." (Clerke.)

Now Laplace's nebular hypothesis being accepted as fact, many millions of years ago, the nebulous ring out of which the earth and moon were formed, separated from the inner mass. The moon was, no doubt, a part of the ring, and is, therefore, as old as the earth. Both were intensely heated liquid or gaseous substances, and the smaller exposed to the greater attractive power of the larger, was pulled into an orbit of revolution about the latter. The earth's tidal action upon the lunar substance, would, in the course of millions of years, gradually change the rotation-rate so as to make it coincide with its period of revolution about the earth. A great tidal wave would rush over the moon's surface in the direction of the earth, and at the same time another would be formed on the opposite side of the moon. As the lunar body cooled, in the lapse of ages, there would result an elongated rigid mass, having its longest axis pointing always towards the earth. As long as the moon remained in the liquid or gaseous state, but contracting, and therefore increasing her distance from the earth, the trend towards a fixed and final shape and fixed periods of rotation and revolution would be very evident. "The evidence for the efficiency in bringing about the actual configuration of the lunar-terrestial system" is not weakened by any contrary hypothesis.

Accepting all of the foregoing with regard to the moon, namely, that millions of years ago our satellite was in a liquid, or viscous, or gaseous condition; that its surface was swept by immense tides produced by the earth's attraction; that its longest axis was made to point always towards the earth; and that the rotation period and revolution period were forced into coincidence; let us see whether the same things are true of other bodies in the solar system.

The discovery of Schiaparelli has made known the fact that Mercury and Venus sustain the same relation to the sun that our moon does to the earth. The close proximity of these planets to the sun when they were in a gaseous state, and the tremendous tidal action of the sun upon their masses, shaped their destiny. But, passing to the earth, a different order of things, that is, a different law, must have been in operation. Our planet turns in one year its entire surface to the sun; her rotation period is not synchronous with that of her period of revolution; and her longest axis does not point toward the sun. Somewhere, then, between Venus and the earth, is the dividing line outside of which the sun's power is so much diminished that earth and all the other outer planets, have their periods of rotation and revolution, none coincident, and their entire surfaces are exposed at some time in their respective revolutions to the sun's rays.

But how is it as to the satellites themselves? We know the condition of our moon and her relation to the earth.

In 1877, Mars was discovered to have two satellites, the outer one at a distance of 14,600 miles from the center of the planet, and the inner distant only 5,800 miles. Now, these distances are in comparison less than the distance of our moon from the earth, and the satellites themselves being acted upon to a less degree, on account of distance, by the solar attractive power, are controlled by the comparatively nearer and therefore greater power of Mars. The fact, too, that the diameter of the larger or inner satellite does not exceed 16 miles, and that of the outer 14 miles, makes it more than probable that the Martial tide-raising power exerted upon these little bodies must compel their rotation and revolution periods to coincide, and their longest axes to be directed towards Mars himself.

The action of the satellites of Mars upon each other may to some extent modify the relations between the periods of rotation and revolution, but owing to their proximity to their primary and his great size as contrasted with theirs, this modification must be dwarfed into insignificance.

Let us now pass to the consideration of the satellites of Jupiter. In the November number of Astronomy and Astro-Physics, appears an article "On Recent Observations of the Satellites of Jupiter," by W. H. Pickering, of the Lowell observatory, Arizona. From that article I quote the following: "As it would seem that some astronomers are still doubtful about the accuracy of my observations made upon these bodies (Jupiter's satellites) in 1892, I will describe one made upon September 18 of the present year (1894), which is, I think, of interest for several reasons. At 16 hours 34 minutes, the 18-inch Brashear telescope showed that the first and third satellites were very near together, and that both of them presented elongated discs, the elongations being nearly at right angles to one another. The second and fourth satellites were also slightly elongated, but in different directions. The 12-inch Clark telescope was then turned upon the planet, and the observations repeated without difficulty. I went next to the 6-inch Clark, and was surprised to find that with a power of 400, not only the elongations of the first and third were easily seen, but even that of the fourth could be detected. I especially noted that the elongations had precisely the same position angles relatively to each other as in the larger instruments." Again, "since the elongations occurred in different directions for the different satellites, the appearance clearly could not be due to atmospheric conditions, or to the eye. Since identically the same appearance was seen in three different telescopes, it could not be instrumental; and, finally, since the elongation has been seen at different times by at least half a dozen different persons, it cannot be a permanent idiosyncrasy."

The elongated forms of the satellites of Jupiter, referred to by Mr. Pickering, can be accounted for on the tidal theory; and if such be the fact, in all probability their periods of rotation and of revolution must be coincident, unless the third and fourth satellites are at a distance from Jupiter proportionally greater than Venus is from the sun, or our moon is from the earth, the masses of Jupiter and his satellites being taken at their estimated values. The difficulty that presents itself with regard to the elongations of the first and third satellites "being at right angles to one another" can easily be put out of the way, when we consider the many different relative positions of the satellites and Jupiter as observed from our earth standpoint. The new inner satellite discovered by Mr. Barnard, of Lick observatory, will, of course, present no difficulty, if my statements with regard to the other satellites be allowed. Although Mr. Proctor says that "there are reasons for believing that the moons of Jupiter are (not all of them, at any rate) in the same condition as our moon", and that "changes of luster occur such as cannot be wholly explained by the rotation of these bodies on their axes, either like our own moon once in each circuit around their primary"; yet, "if the age of Jupiter's satellites corresponds to that of our own moon, the retarding tidal action caused by a planet whose mass is 315 times that of the earth must have brought about a synchronism between the rotation and revolution periods long ere this." The elongation of each of the four outer satellites discovered or observed by Mr. Pickering, the proximity of all of them to their primary, and the comparative masses and densities of the members of the Jovian system, all point unmistakably to the correspondence of the rotation and revolution periods of the satellites respectively.

In like manner it may be affirmed that the satellites of Saturn, Uranus, and Neptune are controlled.

The perturbations produced among the satellites of the major planets upon one another are not sufficient to destroy the validity of a general law such as has been outlined in the foregoing.

We have no reason to discredit the conclusions of Schiaparelli, for they are recognized as the best that have so far been reached. As the force of gravity varies inversely as the squares of the distances, and directly as the product of the masses of the attracting bodies, a glance at the following relations will show the scope of the law we are attempting to unfold:

(a) The sun, at a distance of 67,000,000 miles from the planet Venus, and with a mass 425,000 times as great as that of the planet, has, according to Schiaparelli, forced the rotation and revolution periods of the planet to be coincident.

(b) Beyond Venus, away from the sun, the latter body fails to produce a like result upon the other planets.

(c) The earth is 238,000 miles from her satellite, has a mass 81 times as great, and the two periods are coincident.

(d) Jupiter's first and second satellites are in the same relation to their primary that our moon is to the earth.

Jupiter is 1,167,000 miles from his outer satellite, has a mass 42,480,000 times as great, and has given to the satellite an elongated or ellipsoidal form, a result of the tremendous pull of the planet upon the former plastic condition of the satellite. It must follow that No. 4 has motions just as the first and second have, and always shows the same face to the primary.

(e) The distance, mass, and gravitation relations of the third and fifth Jovian satellites, and of all the moons of Saturn, Uranus, and Neptune, being substantially the same as those of our moon, it is safe to say that their rotation and revolution periods are coincident, and they never show but one face to their primaries.

Whatever we may think as to the moon's past, and however long we may suppose her period of rotation to have been when she started on her career as an independent body, the fact that she turns the same face constantly towards us, tells us of long stretches of time, in her history, that must be measured by millions of years. And upon the hypothesis that millions, and perhaps tens of millions, of years ago, the moon was a mass of liquid or gaseous matter, and that in this condition, she was exposed during all those ages to the earth's pull or attraction, it can be easily seen that the period of her rotation and that of her revolution would be gradually forced into coincidence.

And so, when we consider the facts already established concerning all the satellites of our system, as well as those pertaining to the movements of the planets Mercury and Venus; when we consider the law of gravitation, the masses and the distances of all these bodies; and, further, when we understand the meaning of the observations of Schiaparelli and Pickering, we must conclude that the modern theory of "tidal friction" when applied to the satellites, is true.